Project Report: Causes of mass extinctions: testing impact models_Ward

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Project Progress

This project was instituted to examine the relationship between impact and mass extinction. We know that one of the largest mass extinctions of the past 500 million years was caused by impact (the Cretaceous/Tertiary (K/T) event 65 million years ago (Alvarez et al, 1980)). What of the many other mass extinctions? A major thrust of the University of Washington NASA Astrobiology Institute's research has been to test for hypotheses of impact being related to other mass extinctions. In the third year of our grant we have made significant progress toward understanding the cause of the largest mass extinction of all time, the Permian extinction of 251 million years ago, and the second or third most catastrophic extinction, the Triassic/Jurassic (T/J) event of 200 million years ago. In this summary we will outline this progress.

1. Stable isotope and rates of extinction, Permian extinction, and Triassic/Jurassic extinction events (PI Ward, Co–I Buick, Kring, and NAI NRC post–Doc (with Ward) Garrison

- Permian strata from South Africa. We have concluded research on samples obtained during 2001 in South Africa using the new stable isotope facility at the University of Washington . We have succeeded in obtaining a new curve for both carbonate and organic carbon isotopes from the highest Permian and lower Triassic of this. Our results, coupled with new data about the disappearance of vertebrate fossils in this region suggest that the extinction had a more protracted nature than the signal in both isotopes and extinction metrics at the impact caused K/T event. We believe that our new evidence does not support hypotheses of impact–induced extinction at the end of the Permian (i.e., Becker et al., 2004). These results have been written up as a manuscript now undergoing internal review. It will be submitted to Science Magazine in mid–summer.
- Permian strata from Alberta. We have concluded analysis of material sampled by Garrison at a marine Permian/Triassic boundary section in Alberta . These data, coupled with paleontological data, show an extended period of light stable isotopes after the Permian/Triassic boundary in the region. Again, this pattern does not appear similar to

the pattern observed at the end of the Cretaceous from similar marine facies. Our new data are better explained by a protracted oceanographic event brought about by changes in the atmosphere than an impact event. This work is now being written up for submission.

- Triassic/Jurassic boundary in the Queen Charlotte Islands. During 2003–2004, we finished analyzing carbon isotope data from the T/J section of the Queen Charlotte Islands that was the site of the study by Ward et al. (2001). Our new results, now in press (Ward et al., in press, *Earth and Planetary Science Letters*), demonstrated an extended period of isotopic perturbations occurring after the level of mass extinction. These data do not support an impact event explanation for the T/J mass extinction event.
- T/J boundary, Nevada. In April, 2003, we sampled from the classic T/J section at Muller Canyon . Our results show a series of isotopic perturbations around the boundary that are not consistent with the patterns found at the one known impact extinction boundary, the K/T event. These results have been written and are in review in *Geology* .

2. Helium as an Indicator of Extraterrestrial Impacts

Over the last few years helium concentrations and isotopic compositions of sedimentary rocks have been used to detect important solar system events including catastrophic bolide impacts with Earth at several different extinction horizons. The basic idea is that extraterrestrial matter is highly enriched in the rare isotope of helium (^{3}He) compared with terrestrial material that constitutes most sedimentary rocks. The presence of high concentrations of extraterrestrial ^{3}He coincident with an extinction horizon would provide strong indirect evidence of an extraterrestrial cause for the extinction. Extraterrestrial ^{3}He may be present in fullerenes released directly from an impactor (Becker et al., 2001a) or in interplanetary dust particles (IDPs) (Poreda and Becker, 2003) , . While IDPs accumulate from multiple sources and need not be indicative of a significant extraterrestrial event, an enhanced IDP flux may be associated with showers of long–period comets (Farley et al., 1998) and with major collisions in the asteroid belt (Kortenkamp and Dermott, 1998) . Both of these events raise the likelihood of impact, in some cases enormously so (Hut et al., 1987) . One advantage of using ^{3}He as an impact tracer is that elevated levels associated with major solar system events can last for a few million years (Farley et al., 1998; Kortenkamp and Dermott, 1998) , making detection far easier than the location of a single ejecta layer in a long stratigraphic sequence.

In 2003–2004 we completed detailed helium isotopic investigations of two possibly impact–induced extinction boundaries: the Permian/Triassic and the Triassic/Jurassic.

A. Permian/Triassic Boundary

Multiple lines of evidence have been presented in favor of an extraterrestrial impact associated with the Permian/Triassic (P/T) boundary. Recent observations favoring impact include extraterrestrial noble gases in fullerenes and in IDPs in purported boundary sediments (Becker et al., 2001b; Poreda and Becker, 2003) , meteorite fragments in P/T age sediments from Antarctica

(Basu et al., 2003) , and a proposed impact crater in the Indian Ocean alleged to be of the appropriate age (Becker et al., 2004) . These observations have been very controversial. Some of the original observations could not be reproduced by another laboratory (Farley and Mukhopadhyay, 2001) , the identification of the P/T boundary in relation to the fullerene spike is doubtful in at least one case (Isozaki, 2001) , and the existence of an impact crater and its likely age have been rejected (Renne et al., submitted 2004). Although a great deal of very suggestive data has been published on the topic, no incontrovertible evidence for a P/T−age impact event yet exists.

Helium concentration and isotopic composition were measured in a suite of 33 cherts, siltstones, and shales across the P/T boundary at Opal Creek , Canada (Henderson, 1997) . No extraterrestrial ^{3}He was detected, implying that neither fullerene hosted nor IDP−hosted He is present at or near the boundary. This observation is consistent with similar studies of other P/T sections, but contrasts sharply with reports from a single group of both fullerene and IDP−hosted extraterrestrial ^{3}He at some other P/T sections. If extraterrestrial ^{3}He is present at the P/T boundary, it must be very heterogeneously distributed. As such, we conclude that the ^{3}He−based evidence for impact at P/T time is uncompelling.

While no extraterrestrial ^{3}He was detected, there is a sharp increase in nucleogenic ^{3}He, very close to or at the P/T boundary. This presumably arises from the major lithologic change at this time, from cherts in the Permian to shales and siltstones in the Triassic. Increased nucleogenic ^{3}He is associated with increases in both lithium and organic carbon content into the Triassic. Either the production rate or the retention of this ^{3}He is higher in the shales and silstones than in the cherts. One important conclusion of this new work is that care must be taken to eliminate such artifacts before interpreting changes in ^{3}He concentration in terms of fluctuations in the delivery of ^{3}He from space.

A manuscript has been completed on this work and should be submitted shortly.

B. Triassic/Jurassic Boundary

On the basis of a small Iridium anomaly, Olsen et al., (2002) proposed an extraterrestrial impact in association with the T/J extinction event. Ward et al., (in press), concluded that the stable isotopic evidence argues against such an interpretation. To assess whether ^{3}He provides any insight to this question we analyzed thirty silty limestones spanning 40 meters centered on the T/J boundary, from Muller Canyon , Nevada (Hallam and Wignall, 2000) .

The preliminary results provide no support for extraterrestrial ^{3}He at or near the boundary – no evidence for either fullerene−hosted ^{3}He or enhanced interplanetary dust flux. This conclusion is consistent with work undertaken at several other T/J sections in eastern North America (Farley and Olson, unpublished). Further work is required to conclusively establish the origin of the ^{3}He in this section, but it is probably nucleogenic.

Highlights

- We have recovered detailed carbon isotope curves from a marine and non–marine section of late Permian age, and two marine sections of late–Triassic, early–Jurassic age. These results are not consistent with environmental effects of large body impact on the Earth.
- We have analyzed fossil records across these same horizons. The extinctions do not appear to be sudden/catastrophic.
- We have analyzed for extraterrestrial material from these boundary sections. We do not recognize an unambiguous extraterrestrial signal.

Roadmap Objectives

- ***Objective No. 4.2:*** Foundations of complex life
- ***Objective No. 4.3:*** Effects of extraterrestrial events upon the biosphere
- ***Objective No. 6.2:*** Adaptation and evolution of life beyond Earth

Field Expeditions

Field Trip Name: Triassic of SE Alaska

Start Date: 7/3/03	***End Date:*** 7/12/03
Continent: North America	***Country:*** USA
State/Province: Alaska	***Nearest City/Town:*** Kake
Latitude:	***Longitude:***
Name of site(cave, mine, e.g.):	***Keywords:***
Description of Work: Collection of fossil material for isotopic analysis	
Members Involved:	